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Analysis and Publication of Deer Research Data in Southeast Alaska, 1978–1999

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Research Performance Report
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This is a progress report on continuing research. Information may be refined at a later date.

RESEARCH PERFORMANCE REPORT

STATE: Alaska **STUDY:** 2.12

COOPERATOR: None

GRANT: W-27-3

STUDY TITLE: Analysis and Publication of Deer Research Data in Southeast Alaska, 1978–1999

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SUMMARY

The purpose of this project is to accumulate unpublished data on forest ecology and the Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) for the scientific community, agency personnel, and the public. This is accomplished through participation in professional meetings, consultations with students, and publications for professional and lay audiences.

During this reporting period I co-authored 2 manuscripts currently in review. A third manuscript is attached as an appendix to this paper. Progress continues on 4 additional manuscripts for submission to journals in 2001, and 2 in 2002. Progress continues on a computerized database on deer literature and an annotated bibliography on deer-habitat relationships in Southeast Alaska. Brief descriptions of each of these products and a timeline for completion are provided. A final report will be completed in 2002.

In addition to these publications, I have developed a self-attaching radio collar for deer and elk. I am working with a private company to develop a data logger that will store time/date information on any radiocollared animals coming within a preset distance of the recorder. The snare and the data logger will be used to generate mark-recapture population estimates for introduced elk (*Cervis elaphus*) on Etolin Island.

Key words: elk, *Cervis elaphus*, deer, forest ecology, logging, *Odocoileus hemionus sitkensis*, old growth, Prince William Sound, publications, Southeast Alaska.

CONTENTS

BACKGROUND

Deer are the most abundant, most hunted big game animal in Southeast Alaska. This, in combination with their dependence on old-growth forest habitats, makes them a key ecological indicator species (Hanley 1993, 1996). Deer are also Southeast Alaska's most-studied animal. Research by Dr. David Klein in the early 1960s focused on the physiological response by deer to ranges of varying quality (Klein 1963, Klein 1964, 1965). With the increase in clearcut logging in the 1970s, research focus shifted to logging-related studies under the cooperative leadership of Dr. Olaf Wallmo and Dr. John Schoen. A number of symposia held in the late 1970s and early 1980s attracted good participation and were a valuable means of gathering the best available information on deer to date (e.g., Wallmo and Schoen 1979, Schoen et al. 1981, Meehan et al. 1984). Through the 1970s and 1980s, researchers followed radiocollared deer, or counted tracks or fecal pellet-groups to illustrate patterns of habitat use in cut-over and unlogged landscapes (Leopold and Barrett 1972, Bloom 1978, Wallmo and Schoen 1980, Kirchhoff and Schoen 1983, Mankowski and Peek 1989, Schoen and Kirchhoff 1990, Yeo and Peek 1992). In the 1980s, Dr. Tom Hanley of the Forestry Sciences Lab oversaw a series of studies that focused on the nutritional ecology of deer, seeking explanations for why deer select certain forages and habitat types (Hanley and McKendrick 1983, 1985, Hanley et al. 1984, Hanley et al. 1985, Hanley et al. 1992, Hanley 1996). Flowing from this large accumulation of research were a number of synthesis papers (Hanley et al. 1985, Hanley et al. 1989, Parker et al 1999) and quantitative models designed to predict changes in deer numbers as a result of habitat change (Fagen 1988, Hanley and Rogers 1989, Weyermann et al 1991, Suring et al. 1992). In the last 5–10 years, my deer research has focused on ways to ameliorate the effects of clearcutting on deer habitat by looking at patterns of clearcut logging at the landscape scale (Kirchhoff 1994) and examining the effects of alternative silvicultural prescriptions that may minimize impacts on deer (Kirchhoff and Thomson 1998).

As project leader for deer research in Southeast Alaska since 1988, I have overseen 4 federal aid projects:

1 Evaluation of methods for assessing deer population trends in Southeast Alaska (W-22-6 and W-23-1, 2, 3, 1987–90).

2 Effects of forest fragmentation on deer in Southeast Alaska (W-23-3, 4, 5, W-24-1, 2, 1990–93)

3 Effects of selection logging on deer habitat in Southeast Alaska (W-24-4, 1994-98)

4 Effects of even-aged timber management on survivorship in Sitka black-tailed deer, Southeast Alaska (1996–1999)

Little information from these studies has been published in peer-reviewed journals, and results are generally unavailable to resource managers and the public. Before starting new field studies, I hope this existing data will be published.

OBJECTIVES

The objective of this Federal Aid project is to make an accumulation of unpublished data on deer and forest ecology more readily available to the scientific community, agency personnel, and the public.

METHODS

Final reports on the first 3 of these studies have been completed, and administrative oversight on the 4th (a PhD candidate's project) has been transferred to Dave Person, who was recently hired to supervise predator-prey research in Ketchikan. Most of the planned publications focus on different components of these Federal Aid reports. Most of the planned publications require substantial original writing and, in some cases, new analyses of data. Draft papers are submitted for informal or interagency review before submitting to journals, and changes are made as recommended. Revised final drafts will be submitted to an appropriate journal. Assuming papers are accepted, I will begin the process of responding to reviewer's suggestions and preparing the paper for publication. Papers that are rejected will be substantially revised to address identified weaknesses and either submitted to a different journal or published in-house.

Preparing scientific papers requires good familiarity with current scientific literature. As I read relevant papers, I annotate them for future reference. I intend to compile these in an annotated bibliography and searchable database for broad distribution. Slides and digital photos will also be made readily accessible within the department and to the public for their information and use.

RESULTS

The following technical papers and publications are either in review or in preparation. In this list I include the authorship, planned outlet, planned submission date, and brief description of findings.

Title: Fitting Nonlinear Population Models to Field Data.
Authors: Emlen, J. M., D. C. Freeman, M. D. Kirchhoff and 3 others
Status: In review.
Outlet: *Ecological Applications*
Submission: July 2000
Description: The paper describes a new generation of models that predicts population dynamics of species in a community as a function of local densities, the densities of plant resources per individual, density of competitors and predators, and physical environmental values. The model assumes deer are distributed in an ideal free manner. We used vegetation and deer density data from 97 islands in Southeast Alaska (Kirchhoff 1994) to develop and test the model. A previous paper on this subject was rejected last year. We revised extensively and resubmitted to *Ecological Applications*, where it is currently in review.

Title: Ecoregional Differences in Population Dynamics of Mule and Black-tailed Deer
Authors: J. Heffelfinger, L. Carpenter, L. Bender, G. Erickson, M. Kirchhoff, E. Loft, W. Glascow
Status: In review
Outlet: Book
Submission: August 2000
Description: This book is being written by the Western States and Province Mule Deer Working Group (MDWG), of which I am a member. In this particular chapter, I co-authored the section on the coastal rainforest ecoregion. There is no publication date as yet, but various agencies have agreed to contribute to the publication cost. We also plan to publish a simplified version as a newspaper supplement to make some of the general information in the book accessible to the lay public.

Title: Forest-mammal Associations of Prince William Sound, Alaska
Author: Kirchhoff, M. D.
Status: Complete
Outlet: ADF&G progress report
Submission: n.a.
Description: This paper was tentatively accepted as one of 8 to be published in a special issue of *Biological Conservation*. Due to the fact that some authors did not get their papers completed, the journal dropped plans to publish a special focus issue. I do not believe the paper can be published alone. To make the information accessible, it is included as an appendix in this federal aid report.

Title: Effects of Partial Logging on Stand Growth, Yield, and Structure in Southeast Alaska.
Authors: Kirchhoff, M. D. and S. R.G. Thomson
Status: Manuscript in prep.

Outlet: *Forest Science* or *Western Journal of Applied Forestry*
Submission: 2001
Description: I have reanalyzed the increment core data from Kirchhoff and Thomson (1998) to show growth in ten-year periods before and after date of logging. This technique provides a more distinct release in terms of increased tree growth rates and lends new insights into the relationship between disturbance intensity and stand response. Preliminary indications are that (1) tree growth rates increase as logging intensity (percent of basal area removed) increases and (2) Sitka spruce *(Picea sitkensis*) regenerates adequately under very light selection harvest. We concluded that light selection harvest (1–6 individual trees per 0.2 ha) can occur and still preserve functional winter deer habitat. The published results will be useful to land managers and conservationists who are interested in prescribing effective alternatives to clear-cut logging.

Title: Effects of Partial Logging on the Composition, Abundance and Structure of Understory Vegetation in Southeast Alaska.
Authors: Kirchhoff, M. D. and S. R.G. Thomson
Status: Manuscript in prep.
Outlet: *Canadian Journal of Forest Research* or *Journal of Forestry*
Submission: 2001
Description: Logging by the traditional clear-cut method produces densely stocked, even-aged tree stands that eventually shade out understory vegetation and significantly reduce habitat value for deer. Light partial cutting, in contrast, emulates natural disturbance patterns and appears able to maintain habitat value over the long term. The response of the understory vegetation varies, depending on site conditions (riparian versus upland) and intensity of logging (percent of original basal area removed). Vegetative condition and deer response are measured across a continuum of disturbance intensities to provide managers with guidelines for partial harvesting that maintain habitat value for deer.

Title: Equations for Estimating Biomass and Browse Consumption of Common Deer Forage Plants in Southeast Alaska
Author: Kirchhoff, M. D.
Status: Manuscript in prep.
Outlet: *Journal of Range Management*
Submission: 2001
Description: There are numerous papers in the literature on the subject of predicting plant biomass from various measures. While these are helpful, they suffer some important limitations. For equations to be useful and accurate, they must reflect measures on *randomly* collected plants; they must account for the effects of deer density (or browsing) on the plants; and they must distinguish biomass that is above and below the reach of deer. None of the existing papers from Southeast Alaska does this, and so all tend to over-estimate available biomass for deer. The regression equations I report here

will be for the primary browse species (*Vaccinium spp*) and will incorporate terms for relative browsing intensity. The data were gathered in conjunction with the study on effects of habitat fragmentation on deer. This paper will be useful for measuring vegetative carrying capacity for deer in different habitat types in SE Alaska.

Title: Deer Habitats in Southeast Alaska: Classification and Description.
Authors: Farmer, C. J. and M. D. Kirchhoff
Status: Manuscript in prep.
Outlet: *PNW Research Note* or *NW Science*
Submission: 2001
Discussion: There are numerous classification systems for vegetation in Southeast Alaska based on various measures of stand structure, composition, and biomass. While the classifications may use qualitative or quantitative measurements, most rely on sampling releves, or stands that are subjectively selected. On Heceta Island we sampled vegetation on a random sample of plots that were laid out in a systematic grid (1 km x 1 km) across the island. We will use a cluster analysis to characterize the composition and biomass of understory plants within each functional habitat category. The results will be useful in modeling carrying capacities for deer.

Title: A Self-attaching Radio collar.
Author: Kirchhoff, M. D.
Status: In progress.
Outlet: *Wildlife Society Bulletin*
Submission: 2002
Description: Techniques currently used to radiocollar study animals all require capture and handling. In Southeast Alaska, the requirement of capture has limited efforts primarily to alpine habitats, young clearcuts, beaches, and road edges where deer can be approached and either darted or net-gunned. Success rates are variable with darting, and net-gunning from helicopters is expensive and logistically difficult in remote study areas. More problematic is the fact that we cannot sample deer effectively in forest habitats, leading to a potential for bias in our results. Finally, physical capture and handling increase stress in these deer and associated risk of serious injury or death. I have developed an inexpensive self-collaring snare that carries a lightweight 2-year transmitter. Prototypes have been developed and were tested on Prince of Wales Island this past summer. We halted testing when 1 black bear was inadvertently collared (briefly) and bears detected and disturbed other snares. The collars have been modified to make them less visible, to eliminate the latex expansion segment (which attracted bears), and to armor the transmitter itself in a metal sleeve. We shifted trapping effort to mid-winter when bears are hibernating and male deer and elk do not have antlers.

In conjunction with this effort, I am working with engineers at Global Tracking Systems Inc. (Alberta, Canada) to develop a prototype VHF data logger. The data logger will automatically record time and date when any radiocollared animal comes within a preset distance of the transmitter. If the collaring represents an animal "capture" and the later detection by the data logger represents an unbiased "recapture," then the ratio can be used to calculate a Lincoln-Peterson estimate of total population size. Field experiments will continue through this winter and next spring.

Title: Balancing Predation Risk and Starvation Risk by Deer: Empirical Evidence From Islands in Southeast Alaska.
Authors: M. D. Kirchhoff and C. J. Farmer
Status: Manuscript in prep.
Outlet: *Behavioral Ecology*
Submission: 2002
Description: This research was conducted as part of the forest fragmentation study, the original purpose of which was to assess effects of island size on deer distribution. I found that other factors besides island size (namely, security from predators) had a much greater influence on deer distribution. By carefully monitoring deer densities and forage conditions on 97 islands over a 4-year period and factoring in proximity to large islands with resident wolves, we clearly concluded that deer were making demonstrable tradeoffs between risk of starvation and risk of predation in their habitat (island) selection. Because islands constitute such discrete habitat choices, this is a clean experimental design that nicely demonstrates optimal habitat selection by a large mammal. I am reanalyzing these data using more sophisticated multivariate techniques. I plan to coauthor this paper with Chris Farmer (Ph.D. candidate and ADF&G cooperator), who is testing similar theories about optimal foraging and habitat selection in a terrestrial setting (see job 4 above).

Title: Deer Population Trends in Southeast Alaska- A 20-year history.
Authors: Kirchhoff, M. D., and M. J. Kirchhoff
Status: Manuscript in prep.
Outlet: *ADF&G in-house Publication*
Submission: Not yet scheduled
Description: There are very few survey programs in the country that have been conducted with consistent methodology over more than a 20-year period. The Region's pellet-group survey program, conducted throughout Southeast Alaska each year, is one such example. Although we typically compare each year's results to the previous year's, we have never examined long-term population trends or biogeographical patterns across the archipelago. Some editing may be necessary and assumptions built in before the year-to-year data are directly comparable. Results could be presented by drainage, but more likely, we will be looking for larger-scale and longer-term patterns

using smoothing algorithms and exploratory data techniques. The product should be of high interest to both hunters and biologists.

Title: Sitka Black-tailed Deer – An Annotated Bibliography
Author: Kirchhoff, M. D.
Status: Manuscript in prep.
Outlet: *ADF&G in-house publication*
Submission: Not scheduled
Description: Over the last 20 years, I have gathered (or inherited) a large collection of research papers on Sitka black-tailed deer. Other information is unpublished "gray" literature, including agency reports and administrative studies dating back to the 1950s. Many biologists, especially those who prepare Forest Service EIS's on contract, are unfamiliar with some of this work. Over the past year, I have reviewed and filed over 500 reprints and have begun entering these into a computerized database. However, I suspect the trend toward computerized abstracting services (e.g., Absearch) and online journals may make this system of filing and annotating hard copies obsolete before it is complete. Progress will nonetheless continue through the foreseeable future.

Title: A Searchable Literature and Slide Database on CD-Rom: Deer, Forests, and Conservation Biology
Author: Kirchhoff, M. D.
Status: Product in development
Outlet: *ADF&G in house publication*
Submission: Not scheduled
Description: I would like to transfer the above information on deer, along with literature on forest ecology and conservation biology, to CD-ROM so that the information can be more easily searched and retrieved. This will by no means be a comprehensive database, but it should be a useful contribution. Related to this project, I will label and organize approximately 500 35-mm slides and digital images into a computerized database for use by the region and public.

Title: Old-growth and Wildlife in Southeast Alaska – on the Web.
Author: Kirchhoff, M. D.
Status: Product in development
Outlet: *ADF&G in house publication*
Submission: Not scheduled
Description: I frequently receive requests from teachers to make presentations in their classrooms on wildlife or forest ecology. More recently, tourism operators have asked me to either help train their employees or work as a naturalist on their cruises. I do regularly speak to classes but have declined requests from commercial operators. The opportunity to annually educate students and thousands of cruise ship visitors about wildlife and forest issues in Southeast Alaska is a valuable one. Therefore, I propose developing a web

page that contains the natural history information that people are requesting and provides a forum for answering commonly asked questions. There would be a significant investment of my time in development and creation of the site (linked to the ADF&G web page), but maintaining and updating it would probably be manageable. This would be freely accessible to anyone with an interest, including teachers, locals, tourists, and commercial operators.

CONCLUSIONS AND RECOMMENDATIONS

In working on this project, I found more potentially publishable information than originally anticipated. I plan to complete and submit 4 papers for publication in 2001, and 2 in 2002. Time permitting, there are 4 additional papers or products that could be developed beyond this, including an annotated bibliography, educational materials for teachers on the web, and an analysis of more than 20 years of data on deer population trends (Kirchhoff 2000).

The scope of work remaining exceeds what can reasonably be accomplished in the remaining year of this project. I will work on the peer-reviewed technical articles as my first priority. I will also be developing a study plan for future research on deer and elk interactions. If that work is funded, I will continue to devote time to publishing as much of the deer backlog as possible. I appreciate having the opportunity to focus my effort and attention on publishing this information.

ACKNOWLEDGMENTS

I thank Kim Titus for his support and advice on this project and Mary Hicks for her editorial assistance. I'd like to acknowledge two of my mentors, John Schoen (retired) and Olaf Wallmo (deceased), whose pioneering work set the standard for deer research in Southeast Alaska.

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APPENDIX

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FOREST-MAMMAL ASSOCIATIONS OF PRINCE WILLIAM SOUND, ALASKA

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Abstract: The number of mammal species in Prince William Sound is relatively small compared to analogous areas in lower latitudes. An estimated 39 mammal species occur in Prince William Sound; approximately 30 of those regularly use forest habitats. Included in this group are a number of high-profile species, such as the wolf *Canis lupus*, and the brown bear *Ursus arctos*, that are threatened or endangered elsewhere in North America. Some of these species find food and shelter in the forest, but are more influenced by human disturbance than by habitat attributes per se. Other species, like the marten *Martes americana*, and Sitka black-tailed deer *Odocoileus hemionus sitkensis* are obligate forest users, dependant on compositional and structural attributes unique to old-growth forests. In general, the highest-value forests include more productive lowland sites, particularly adjacent to the coast and along rivers.

Three key features of the Prince William Sound ecosystem set it apart from other areas, and contribute to sustaining a globally significant mammal fauna: (1) it encompasses a very large, essentially pristine area, (2) it includes significant old-growth forest, and (3) it envelops a productive, marine ecosystem. The long-term conservation of the mammal fauna in Prince William Sound hinges on how well these 3 attributes are maintained. A conservation strategy that focuses on protection of rare, at-risk habitats offers the most practical and effective means of accomplishing this goal.

BIOLOGICAL CONSERVATION 00(0):000–000

Key words: Alaska, conservation, old-growth forest, mammals, Prince William Sound.

Prince William Sound is a remote, largely undeveloped region, characterized by extremes of climate and physiography, and at lower elevations, by extensive old-growth forest. The mammal fauna of the region, while not especially diverse, is well represented by large, wide-ranging predators, some of which are threatened or endangered outside Alaska. We know that most of the mammals in Prince William Sound use, or are associated with forest habitat. Beyond that, our understanding of wildlife/old-growth relationships is still rudimentary. Our appreciation of old-growth as important wildlife habitat, in general, is newly evolved (Schoen et al. 1981), and research on old-growth habitat relationships in Alaska is limited to a handful of high-profile species (Schoen et al 1988, Hanley et al. 1989). Nevertheless, these and other studies provide valuable insights into how the forest functions to provide food and shelter for a variety of key species, and is suggestive of it's importance to a broader array of mammals.

Information on the presence or absence of individual mammal species in Prince William Sound was drawn from a variety of sources, including species lists compiled by the U.S. Forest Service, The Nature Conservancy, and local naturalists. Information on wildlife-forest relationships is drawn from research conducted both in Prince William Sound, and in Southeast Alaska where environmental conditions are similar. In presenting this information, I concentrate on functional relationships between forest habitat and some better-known mammals, so that inferences might be made for other species on which research is lacking.

STUDY AREA

The study area centers on Prince William Sound in Southcentral Alaska, and includes all mainland drainages flowing into the Sound, as well as islands within the Sound itself. The area is bounded by the Kenai Peninsula to the west, the Chugach Mountains to the north, and the Copper River Delta to the east (Figure 1). The topography is generally steep and rugged, the product of recent and ongoing tectonic uplift (Juday, this proceedings).

The climate is strongly maritime, with cool temperatures and abundant precipitation year-round. Average annual snowfall at sea level in Cordova is variable, ranging from 150-650 cm per year, with a mean snowfall of 252 cm. The big islands in Prince William Sound (Hawkins, Hinchinbrook, Montague) experience significantly milder temperatures, and lower snowfall, than drainages on the mainland coast. Tree growth is generally limited to elevations below 500 m.

Wildfire is virtually non-exisitent in this region, with the principal agent of forest disturbance being wind, which typically topples individual old trees, or small groups of

trees, during fall storms. This pattern of "high frequency-low magnitude" disturbance is responsible for the all-aged structure of the forest, the discontinuous canopy, and the diverse understory that characterizes temperate-zone rainforests (Alaback and Juday 1989, Boughten et al. 1992). The forest ecology of this region has been summarized by Alaback (this proceedings).

Because of the relatively harsh environment, the forests of Prince William Sound are more sparsely distributed, and the individual trees smaller in size, than elsewhere in the temperate rainforest biome (Farr and Harris 1979). About 18% of the land base in Prince William Sound is forested, compared to 57% in southeast Alaska (Hutchinson 1967). The nonforested land is composed of treeless rock, alpine and extensive muskeg areas. The forested land is dominated by Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*) and mountain hemlock (*Tsuga mertensiana*) (Vierack et al. 1992). Understory plant associations common to this region have been described by Eck (1983) and Borchers et al. (1989).

The forests of Prince William Sound are relatively pristine. With the exception of limited logging during the early 1900's for local construction needs (wharfs, fish traps, and canneries), little industrial-scale logging has taken place. That situation is changing. In recent years, much of the most productive forestlands in the Sound have transferred to private ownership under the 1970 Alaska Native Claims Settlement Act. Clearcut logging has already commenced on these lands, and is expected to continue through at least the next 5-10 years. The balance of the forestland in Prince William Sound lies within the Chugach National Forest. Approximately 2,000 acres had been logged in the Chugach National Forest prior to 1989. In Spring of 1989, following the Exxon Valdex oil spill, the Forest Service halted all timber sale plans for Prince William Sound (Warren Oja, USFS, pers. comm.). Given changing public demands for this area, and the lack of economic timber, resumption of commercial logging on National Forest lands in Prince William Sound appears unlikely (G. Lehnhausen, USFS, pers. commun.).

MAMMAL-FOREST ASSOCIATIONS

The number of species associated with forest habitat depends on one’s definition of "forest", and on what constitutes a meaningful "association". For this paper, I've chosen criteria for both that are relatively inclusive. Forestland is "land that is at least 10% stocked by trees of any size and capable of producing timber or other wood products" (Hutchison 1967:54). This definition includes a wide range of age classes, from early successional forest habitats to old growth. It also includes a wide range of productivity classes, from scrub forest to "high-volume" stands of large spruce and hemlock. I include

stands of cottonwood Populus balsamifera, but do not include woody shrub communities dominated by alders (e.g., Alnus crispa) and willow Salix spp., which are common in areas of Prince William Sound.

I assume an animal is "associated" with forest habitat if it makes regular, significant use of the forest, and finds essential food, water, or shelter there. The frequency and duration of this use can be quite low. For example, mountain goats Oreamnos americanus live mostly above timberline, but do sometimes move into the forest to escape deep snow. Thus, I consider them forest associated. The association can also be indirect. For example, the structure or composition of the forest vegetation may not be important to a predator, but may be essential to the predator's prey. Because that predator finds its primary food in the forest, the predator is also a forest-associated species.

Species Diversity

Species diversity, or richness, generally decreases with increasing latitude (Simpson 1964). We see this pattern reflected in the mammals of the temperate rainforest biome, where along the Oregon coast there are 65 mammals (Maser et al. 1984), compared to 51 in southeast Alaskan (Taylor 1979), and 39 in Prince William Sound (Nature Conservancy, unpubl. data). The reason for this decline is generally attributable to harsher environmental conditions, young, poorly differentiated soils, and fewer plant species and community types at higher latitudes.

Simple numbers of species, however, may be an inappropriate measure of how unique or important an area is in terms of its contribution to biodiversity (Diamond 1976). In conservation planning, priorities are commonly placed on "keystone" species (which play critical roles in ecosystems), "umbrella species" (which require large, wild areas that if protected, will bring many other species with them), and "flagship" species (charismatic species that serve as popular symbols of conservation) (Noss 1993). Prince William Sound supports a number of large mammals that fit one or more of these criteria, including the wolf (Canis lupus), brown bear (*Ursus arctos*), black bear (*Ursus americanus*), and Moose (*Alces alces*). Other species, like Sitka black-tailed deer, can serve as useful "ecological indicators" of the balance between economic development and biological conservation (Hanley 1993).

Forest Associations

Of the 39 mammals believed to occur within Prince William Sound, I consider 30 to be "associated" with forested habitat (Table 1). The degree of association, or dependency, obviously varies from species to species, and among taxonomic orders. In

some cases, only very general information on distribution and habitat use is available, while in others, there is an extensive base of research to draw from. The following species accounts focus on forest-associated animals for which we have the most information: the large ungulates, major predators, and furbearers.

Sitka black-tailed deer (*Odocoileus hemionus sitkensis*)

Sitka Black-tailed deer were first introduced into Prince William Sound in 1916 (Burris and McKnight 1973), and are now well established on all of the islands and on portions of the mainland coast from the Copper River north to St. Matthews Bay and from Wells Passage South to Port Bainbridge (ADF&G 1973). Moderate-density wintering areas on the mainland are found along coastal lowlands from Gravina Point to Simpson Bay. Deer are much more abundant on the islands of Prince William Sound than on the mainland. The highest winter deer densities are found in low elevation forest habitat on Montague, Hinchinbrook, and Hawkins Islands.

Old-growth forest provides essential winter habitat for deer in Prince William Sound. Research on Hinchinbrook Island (Shishido 1986) and in southeast Alaska (Schoen and Kirchhoff 1990) has documented almost exclusive use (93–99%) of forest habitat by deer in winter. The canopy modifies the forest floor environment by slowing radiant heat loss and intercepting snow. The forest canopy intercepts up to 66% of the incipient snow (Kirchhoff and Schoen 1987), decreases costs of locomotion (Parker et al. 194), and increases availability of forage (Hanley and McKendrick 1985). Important winter foods for deer include blueberry (*Vaccinium spp*)., evergreen forbs (e.g., *Cornus canadensis, Rubus pedatus, Coptis aspleniifolia*), and arboreal lichens (e.g., *Usnea* spp, *Allectoria* spp.) (Schoen et al. 1982, Hanley et al. 1985).

All old-growth stands are not equally valuable. Deer use a wide variety of habitat types over the course of a year, but high-volume stands (i.e., stands with large wood volumes, or large-sized trees) intercept snow most effectively (Kirchhoff and Schoen 1987), and are strongly preferred by deer in winter (Kirchhoff and Schoen 1990). These stands are typically found at lower elevations, closer to the coast, and represent a relatively small fraction of the total forest area.

Traditionally, clearcut logging is believed to benefit species like deer by increasing forage production in young clearcuts and increasing "edge" (Schoen et al. 1981). While that may be true elsewhere, in Alaska, increased forage production is generally negated by deep snow which buries forage in young clearcuts (Wallmo and Schoen 1980). More important, however, is what happens 25–30 years after old growth is logged. Regeneration of young conifers is so swift and complete, that young clearcuts are soon transformed into

densely stocked second-growth stands with insufficient light penetration to sustain understory growth (Alaback 1982). These barren conditions persist for a century or more after canopy closure, and are difficult to mitigate silviculturally (Alaback and Tappeiner 1984).

Moose (*Alces alces*)

Moose are found on the mainland coast in the eastern Sound from the Eyak River south. On the western shore, small numbers of moose are found in the Nellie Juan River drainage and the head of Kings Bay (ADF&G 1973). In winter, moose concentration areas are found along the major river valleys which drain into the Copper River Delta and Controller Bay (ADF&G 1973).

Because of their large size, moose are less affected by snow than Sitka black-tailed deer, and are less strongly associated with forest habitats. Studies in southeast Alaska (Doerr 1983, 1984, Hundertmark et al. 1983, Craighead et al. 1984) show that a number of forest types are used by moose, primarily in winter. These include old-growth spruce-hemlock forests, spruce river-terrace forests, and spruce-cottonwood forests. On the Copper River Delta in Prince William Sound, moose make extensive use of riparian stringers of alder and willow, but generally avoid dense conifer forest (MacCracken 1992).

Young clearcuts up to 30 years of age can provide important foraging sites for moose during seasons or years with low snowfall (Doerr 1984). However, with advancing forest succession, browse species will eventually be shaded out by regenerating conifers, and the site will become very poor habitat for moose in any season. Both Doerr (1984) and Hundertmark et al. (1983) recommended that forested habitats near high-density feeding, breeding, and movement areas be excluded from timber harvest to provide for the winter habitat needs of moose. This recommendation can be extended to Prince William Sound where it would apply to narrow stringers of riparian forest along stream courses in moose winter range.

Mountain goat (*Oreamnos americanus*)

Mountain goats are widely distributed along the mainland coast of Prince William Sound. The highest populations are found from the Rude River to Unakwik Inlet in the north, and near the Sargent Ice field in the southwest corner of the Sound (ADF&G 1973, Roy Nowlin, ADF&G, pers. commun.). Mountain goats are absent from the islands.

Mountain goats in coastal Alaska generally inhabit steep, broken terrain above treeline, however, goats also make extensive use of forested habitat (Fox 1979, 1983, Schoen and Kirchhoff 1982, Smith 1985). This is particularly true in areas subject to wet,

heavy snows. In southern southeast Alaska, where alpine areas are covered with snow for 5–6 months each year, goats wintered almost exclusively on forested slopes in commercial quality timber (Smith 1985). In Prince William Sound, goats regularly use the forest in winter, and are occasionally seen at low elevations near tidewater (R. Nowlin, ADF&G, pers. commun.).

Logging in important goat wintering areas has the potential to reduce goat populations. Goat surveys in the vicinity of Icy Bay, where goat winter range has been logged, indicate populations declines of over 50%, while populations in adjacent unlogged areas have either increased or remained stable over the same time period (ADF&G, R. Nowlin, unpubl. data).

Even where logging does not impact goat winter range directly, logging roads into previously remote areas greatly increase accessibility for hunters, and can make goat populations vulnerable to over-harvest. In southeast Alaska, selected areas have been closed to hunting in order to protect small goat populations near proposed logging roads and camps. Wildlife managers should carefully monitor goat populations near newly built access roads, and be prepared to implement harvest restrictions to protect vulnerable populations.

Brown Bear (*Ursus arctos*)

Brown bears are found primarily on the large islands and western mainland portion of Prince William Sound. Known concentration areas include the heads of Simpson Bay, Sheep Bay, Port Gravina and Port Fidalgo on the mainland, Port Etches and Constantine Harbor on Hinchinbrook Island, and Port Chalmers and Zaikof Bay on the Montague Island (ADF&G 1973). The big islands in Prince William Sound (Hawkins, Hinchinbrook and Montague) are relatively productive, and are known for producing large brown bears.

Brown bears are not obligate forest dwellers, as evidenced by their successful exploitation of treeless landscapes in Canada, and interior and northern Alaska. However, in southeast Alaska and parts of Prince William Sound, brown bears occur in substantially higher densities than interior or more northerly regions. The forest is important habitat for coastal bears, and in southeast Alaska, is used more than any other habitat type through the course of a year (Schoen and Beier 1986).

Forest use by brown bears is highest during the late summer when bears are concentrated along streams, feeding on returning salmon Oncorhynchus spp. When not actively catching salmon, bears spend time resting in day beds usually within 100 m of the stream (ADF&G data, unpubl.). Other important food resources are commonly found in riparian and estuarine zones, including sedge (*Carex* spp)., skunk cabbage (*Lysichiton*

americanum), devil's club (*Oplopanax horridus*), blueberry, and stink currant (*Ribes bracteosum*) (McCarthy 1989).

Brown bears, more than most other animals, are considered a "wilderness-associated" species. Historically, brown/grizzly bear distribution has become restricted as development and increasing access brings people into contact with bears (Schoen 1990). Studies in southeast Alaska have documented a strong relationship between increased road access and increased bear mortality (Titus 1991). Measures to minimize adverse impacts on bears include proper location of camps (away from bear concentration areas), required incineration of camp garbage, restricted use of firearms by camp employees, and closure of roads (by gating or barriers) after the logging is completed (McLellan 1990, Titus 1991).

Black Bear (*Usrus americanus*)

Black bears are widely distributed throughout the mainland of Prince William Sound. They do not occur on the islands. Known concentration areas include Simpson Bay, Sheep Bay, Port Gravina, and Port Fidalgo on the east shore, and Kings Bay and Passage Canal on the west shore (ADF&G 1973). Black bears also concentrate along salmon spawning streams throughout the mainland coast in late summer and early fall.

Black bears utilize young clearcuts (< 25 years old) for foraging on green plants and berries, however, as the clearcut matures into even-aged second growth, it will produce very little food for bears. In addition to lacking food, older second-growth stands lack structural components needed by black bears for denning. In southeast Alaska, black bears den above ground in large diameter hollow logs and rotten stumps of western hemlock trees (Erickson et al. 1982). These structural features are characteristic of old-growth stands, and are present in young clearcuts, but are not replaced as existing structures decay. Silvicultural prescriptions that specify retention of large standing snags, and large-diameter green trees in cutting units, should provide a future supply of black bear denning habitat in these areas.

Black bears are more closely associated with forest habitats than brown bears. In addition to salmon, they consume large amounts of sedge and horsetail Equisetum spp. in the spring, and a variety of berries (especially blueberries) through the summer and fall (Johnson 1989). Black bears are also believed to be efficient predators on deer fawns in early summer (Smith et al. 1986).

Black bears are relatively tolerant of human activity and are readily attracted to dump sites and household garbage. This behavior makes them relatively vulnerable to both legal and illegal hunting, particularly in rural areas where extensive road systems provide

easy access. As with brown bears, road management measures may need to be implemented to control access and limit mortality in some areas.

Wolf (*Canis lupus*)

Wolves occur in low numbers across the mainland portion of Prince William Sound and on Hawkins and Hinchinbrook Islands; they have not been noted on the islands in the western sound, including Bainbridge, Evans, LaTouche, Montague, Knight, and Naked Islands (ADF&G 1973). Wolf populations are closely tied to the availability of prey, especially ungulates. Deer, goats, and moose are all utilized by wolves, as well as salmon (in the fall), and beaver (*Castor canadensis*).

Wolves are highly adaptable animals, and their habitat use is largely dictated by where they find their prey. Wolves are most closely associated with forest habitats where deer are their primary large prey species. Timber harvesting and development will indirectly affect wolves through the effect on their prey base. In Southeast Alaska, the minimum density of deer needed to sustain a population of wolves is estimated at 6-8 deer/km^2 (16–21 deer/mi^2) (Person et al. 1996).

Trapping and hunting can reduce wolf populations where roads provide easy access. Studies in the lower 48 states and Canada have shown a strong relationship between road density and the presence or absence of wolves (Thiel 1985, Mech 1989). It is unlikely that road densities associated with planned logging in Prince William Sound will exceed the thresholds reported in the literature, however, it may be advisable to minimize road building, or restrict access in areas heavily used by wolves as travel corridors. Because the terrain is steep, and suitable habitat is largely limited to low-lying coastal areas and passes, wolf travel routes in Prince William Sound are readily identifiable.

Wolverine (*Gulo gulo*)

The wolverine has disappeared over much of its historic range in the lower 48 states, but is still widely distributed in Alaska. Wolverines reportedly occur on the mainland and larger islands of Prince William Sound (ADF&G 1973), but are probably most common on the eastern shore where there range overlaps with the hare Lepus americanus. Wolverines feed primarily on small mammals and carrion, but large ungulates such as deer and mountain goats may also be important. Wolverines travel widely throughout the year, moving to lower elevations in winter (e.g., forested habitat) where food supplies are more abundant (Taylor 1989).

Lynx (*Felis lynx*)

Lynx are occasionally seen along the eastern shore of Prince William Sound, primarily east of the Rude River (ADF&G 1978). They do not occur on the islands or western shore. They frequent forested terrain, and prey primarily on hare and other small mammals and birds (Berrie et al. 1989). Home ranges are large, and densities are low. The high value of their pelts, ease of capture, and low natural densities make lynx vulnerable to overharvest (Berrie et al. 1989). Access and take should be carefully regulated in road-accessible areas.

Coyote (*Canis latrans*)

Coyotes have expanded their range into Alaska relatively recently (since early 1900s) and are common today in only a few locales, including the Copper River Valley (Cornelius 1989). Its range in Prince William Sound is limited to the eastern shore, south of Valdez Arm (ADF&G 1978), where it feeds primarily on hares, small mammals, birds, bird eggs and carrion. The coyote may use forested habitat, but like the wolf, is able to exploit a wide variety of non-forest habitats effectively. Coyotes are less sensitive to human disturbance than wolves.

Red Fox (*Vulpes vulpes*)

The red fox is found in low numbers on the eastern mainland portion of Prince William Sound south of the Rude River (ADF&G 1978). Red fox are generally excluded from areas where coyotes are abundant. Red foxes are omnivorous, eating squirrels, hares, birds, eggs, insects, vegetation and carrion (Jennings 1989). Their natural enemies include wolves, coyotes, lynx, wolverines, and bears (Jennings 1989). Fox are commonly associated with forested habitats in Prince William Sound where their principal prey are found.

Marten (*Martes americana*)

Marten are found on the mainland of Prince William Sound, but not on the islands (ADF&G 1978). Population densities throughout the area are low (R, Nowlin, ADF&G, pers commun.).

Throughout its North American range, the marten is associated with coniferous forests. Recent studies have more specifically documented the importance of old growth as marten habitat (Meslow et al. 1981, Bissonette et al. 1989). Old-growth forests provide important structural characteristics for marten, including overstory canopy, fallen logs, trees with large exposed root systems, and abundant understory (Meslow et al. 1981, Clark

et al. 1987). These attributes serve to protect marten from predation, and provide preferred foraging, resting, and denning sites. Research conducted in southeast Alaska and elsewhere suggests that clearcut logging has negative impacts on marten (Flynn 1991). Young clearcuts lack the cover required by marten, and have lower densities of preferred prey species compared to mature forest (Campbell 1979). As the clearcut matures into second growth, the canopy becomes very dense; the prey base disappears; and the habitat value of the stand declines further (Spencer et al. 1983). In Southeast Alaska, old-growth forest located in the beach fringe and riparian zones appear to be especially important habitat for marten (Suring et al. 1992).

In Prince William Sound, as in Southeast Alaska, most trapping effort occurs along the coastline. Large interior areas away from the coast are relatively inaccessible and serve as important refugia for marten and other furbearers. Animals trapped on the periphery are continually replaced by individuals dispersing from the interior habitats. Road building associated with clearcut logging increases access to interior areas, effectively eliminating the refugia. In Southeast Alaska, managers have addressed this problem by restricting the use of motorized vehicles for the trapping of marten in some heavily roaded areas. Similar restrictions might be considered to protect vulnerable furbearer populations in Prince William Sound, especially where suitable forest habitat is naturally limited.

Mink (*Mustela vision*)

Mink are widely distributed across the islands and mainland of Prince William Sound (ADF&G 1978). They are primarily associated with forest habitat in close proximity to the coastline or riparian areas where they forage on a wide variety of foods, including, fish, birds, bird eggs, insects, crabs, clams, and small mammals (Burns 1989). In comparison with marten, mink are generally more dependent on the intertidal zone, and less dependent on the forest.

Ermine (*Mustela erminea*)

Ermines, or short-tailed weasels, are distributed on the mainland of Prince William Sound, as well as on Hawkins, Hinchinbrook, and Bligh Islands in the eastern sound (ADF&G 1978). Populations are highly cyclic, depending on the local abundance of small mammals, their primary food. Weasels use a wide variety of habitats, including forest, and have occasionally been seen in trees (Lieb 1989). Their use of forest habitats is probably tied closely with the distribution and abundance of the northern red-backed vole Clethrionomys rutilus, which is common in hemlock-spruce forest.

The least weasel mustela nivalis reportedly occurs in Prince William Sound (Nature Conservancy, unpubl. data), but its distribution is poorly known. Habitat use and food habits are similar to the ermine, although it's movements and home range are typically much smaller (Lieb 1989).

River Otter (*Lutra canadensis*)

The river otter is widely distributed throughout the islands and mainland of Prince William Sound (ADF&G 1978) where it is found in close association with marine habitat. Otters prefer coastal habitats that are characterized by convex shorelines, steep beaches, and bedrock substrates (Larsen 1983, Woolington 1984). These habitats tend to be productive of fish species that otters prey on, and the short, steep beaches minimize the otter's exposure to predation (Larsen 1984).

River otters also make extensive use of upland habitats within 30 m of the beach. Preferred daytime resting sites are burrows formed beneath the roots of conifer trees and decaying snags (mean dbh of 85 cm), in stands with a canopy closure greater than 50% (Larsen 1983). Although most of the otter activity occurs near the shoreline, female otters move up to 0.8 km inland to find natal denning sites, usually near streams in well-drained old-growth habitat (Woolington 1984).

River otters avoid beach areas adjacent to clearcuts, even when those beaches exhibit the desired topographic characteristics (Larsen 1983). This is apparently due to dense shrub growth, extensive slash, and lack of overstory cover typical of 5-20 year old clearcuts. Both Larsen (1983) and Woolington (1984) recommended leaving an uncut buffer of timber (50-75 m) along beaches to meet otter habitat requirements. In addition, roads should be placed so that they are not adjacent to steep rocky coastlines, or along lower river courses that act as corridors between natal den sites and foraging areas on the coastline.

DISCUSSION

The terrestrial environment in Prince William Sound, particularly on the mainland, is rigorous and relatively unproductive compared to analogous coastal areas in lower latitudes. Species diversity is low, and population density for most species is low as well. In sharp contrast with this is the marine environment, which is highly productive and diverse. Not surprisingly, many of the most successful terrestrial species (in terms of density) are closely associated with productive marine and stream environments. Some, like river otters, mink, brown bears, and black bears, feed primarily in riparian habitats,

intertidal zones, estuaries, and rivers. Others are attracted to coastal habitats becasue of the ocean's moderating influence on ambient air temperature and snowfall.

The forest plays a similar role. The forest intercepts snow and rain, blocks radiant heat loss, reduces wind speeds, moderates stream flow, and provides a generally stable, favorable environment. This, along with the food resources and habitat structure typical of old-growth forest, make this habitat extremely important to a variety of mammals, particularly in winter. Among those species that benefit most directly from the forests moderating influence are deer, goats, and squirrels.

In Prince William Sound, as in Southeast Alaska, By directly or indirectly providing food to these terrestrial species, the marine ecosystem functions as a net exporter of energy and nutrients to the terrestrial ecosystem. Even species that do not depend directly on the marine environment for food, find better habitat near the coast or rivers where the land is generally most productive. (e.g., riparian or beach-fringe habitats). Examples include deer, moose, wolves, and a number of bats, shrews and small rodents.

Another interesting pattern emerges with respect to the distribution and abundance of mammals on the islands of Prince William Sound. Island biogeography theory correctly predicts that islands in Prince William Sound (as in southeast Alaska) should have fewer species than the mainland. The reasons for this are varied. Some islands are either too small (e.g., for wolves and bears), lack specialized habitat (e.g., for moose), or are unreachable by animals that don't swim well (e.g., lynx, marten, porcupines). It is noteworthy that while species richness on islands is low, population densities of certain species is often very high (e.g., deer, river otter). This is because islands invariably have higher proportions of productive intertidal, riparian, and estuarine habitats, more productive forestland, less severe weather, and fewer predators (e.g, wolves, lynx, fox, and black bears) than the mainland. For species like deer, which are limited by winter weather and, in some cases, predation, the only place where they will ever reach high densities is on the islands.

CONSERVATION STRATEGIES

Three key features of the terrestrial Prince William Sound ecosystem that set it apart from other ecosystems in North America, and contribute to sustaining a globally significant mammal fauna: (1) the ecosystem encompasses a very large, relatively pristine area, (2) forested lands are primarily old growth, and (3) the area contains a highly productive marine ecosystem. Ultimately, the long-term conservation of the mammal fauna in Prince William Sound hinges on how well these 3 attributes are maintained. A variety of conservation approaches might be considered for preserving biotic diversity in

Prince William Sound (e.g., Suring et al., this issue, Noss 1993). For discussion purposes, I reference 2 fundamental approaches. One approach is to protect large areas for species which are area-sensitive, or disturbance-sensitive, such as wolves and brown bears. The conservation "net" or “umbrella” would, because of the large land areas involved, capture the essential habitats of many other species, even those whose habitat needs (and, indeed, existence) may be unknown. The second approach is to focus narrowly on protecting specific habitats, notably those that are either most rare and/or at risk of development, which might otherwise fall through this safety net. This approach presumes an adequate supply of common, low-risk habitats, and targets rare or highly specialized species and habitats for protection.

Neither of these approaches is mutually exclusive, and elements of each can, and should, be considered in developing an effective conservation strategy. Additionally, one should not ignore habitat conditions in the matrix surrounding a system of reserves (Franklin 1993). Where pressure to extract commodity resources is high, or where habitat is already heavily impaired, the protection or restoration of habitat corridors between reserves should be considered. Riparian areas and coastal beach fringe habitats have intrinsically high value and are well suited to this purpose (Naiman et al. 1993). Where the ecosystem is large and relatively pristine, as in Prince William Sound, other options for maintaining “comnectivity” exist. The functional integrity of the habitat may be preserved by “softening” the matrix or dispersing rather than concentrating impacts (e.g., single-tree selection harvesting versus clear-cut logging). This makes the matrix more hospitable to dispersing organisms (Franklin 1993) and may obviate the need for “hard” corridors.

It is unlikely that large portions of Prince William Sound will be roaded or developed given the quality and quantity of existing timber and known mineral resources in the region. Large blocks of de facto wilderness will always exist (especially on the mainland), regardless of whether such designations are officially recognized. On the other hand, where mineral (e.g., coal) of timber resource values are high, development pressure is more imminent. In the near term, focussing our attention on those acres is a more efficient and cost-effective strategy for protecting biodiversity. For example, biodiversity “hot spots” such as riparian stands, or the beach fringe, are prime candidates for special protective measures. These more valuable areas could be deferred from timber harvesting and road-building activities in favor of developing less sensitive lands.

Regardless of the approach (es) adopted, it is highly desirable that conservation strategies be considered before important options are foreclosed. Because Alaska’s ecosystems are still healthy and largely unimpaired, we have an unprecedented opportunity for proactive conservation planning (Schoen and West 1994)

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Table 1 Mammals associated with forest habitat in Prince William Sound.

INSECTIVORA

- Masked Shrew (Sorex cinerus)
- Dusky Shrew (Sorex obscurus)
- Northern Water Shrew (Sorex palustris)

CHIROPTERA

- Little Brown Bat (Myotis lucifugous)
- Silver-haired Bat (Lasionycteris noctivagans)

LAGOMORPHA

- Snowshoe Hare (Lepus americanus)

RODENTIA

- Red Squirrel (Tamiascuris hudsonicus)
- Northern Flying Squirrel (Glaucomys sabrinus)
- Beaver (Castor canadensis)
- Northern Red-backed Vole (Clethrionomys rutilus)
- Tundra vole (Microtus oceonomus)
- Northern Bog Lemming (Synaptomys borealis)
- Meadow Jumping Mouse (Zapus hudsonius)
- Meadow vole (Microtus pennsyvanicus)
- Porcupine (Erethizon dorsatum)

CARNIVORA

- Coyote (Canis latrans)
- Wolf (Canis lupus)
- Red Fox (Vulpes vulpes)
- Black Bear (Ursus americanus)
- Brown Bear (Ursus arctos)
- Marten (Martes americana)
- Ermine (Mustela ermina)
- Least Weasel (Mustela nivalis)
- Mink (Mustela vision)
- Wolverine (Gulo gulo)

River Otter (Lutra canadensis)
Lynx (Felis lynx)

ARTIODACTYLA

Sitka black-tailed deer (Odocoileus hemionus sitkensis)
Moose (Alces alces)
Mountain Goat (Oreamnos americanus)